APPENDIX 1

KANSAS DEPARTMENT

OF

HEALTH & ENVIRONMENT

Division of Environment

Bureau of Water

WATER MAIN DISINFECTION PROCEDURES

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WATER MAIN DISINFECTION PROCEDURES

All new or repaired potable water lines in the public water supply system must be disinfected before they are put into service. These disinfection procedures are based on the AWWA Standard For Disinfecting Water Mains, C651-92. A copy of the complete standard is available for review at the KDHE office, Building 283 Forbes Field, Topeka, Kansas. A copy of the standard may also be obtained from the American Water Works Association, 6666 West Quincy Avenue, Denver Colorado, 80235.

Nonemergency Water Main Disinfection Procedures

The basic steps in nonemergency disinfection of water mains are the following:

1. Prevent the introduction of contaminated material into the main during the installation process.

2. Flush the main or otherwise utilize methods to remove any contaminants that have entered the main.

3. Chlorinate the main by use of the tablet, continuous, or slug method and maintain the specified chlorine residual for the minimum required contact time.

4. Flush the heavily chlorinated water from the main. Dispose of the chlorinated water in a manner that will not adversely impact the environment.

5. Confirm the effectiveness of the disinfection procedure through bacteriological testing. This step is recommended by KDHE but not required.

Step 1. Preventive Measures During Construction

During construction, the interior as well as all sealing surfaces of pipe, fittings, and other accessories should be kept as clean as possible. Inspect the interior of all pipes prior to installation. If dirt enters the pipe, it should be removed and the affected interior of the pipe swabbed with a 1% chlorine solution. All openings in pipelines should be closed with watertight plugs whenever the trench is unattended. Sealing, lubricating, or gasket materials used in pipe installation should be stored and handled in a manner that avoids contamination and be suitable for use with potable water.

Step 2. Preliminary Flushing of Mains

Before being chlorinated, the main should be completely filled with water to eliminate air pockets and then flushed to purge the line of dirt and debris. This is typically conducted after the completion of the leakage and pressure tests. Ineffective removal of dirt and debris from lines prior to disinfection often leads to failed bacterial tests, requiring repeated disinfection. Preliminary flushing should be accomplished at a rate of at least 2.5 ft/sec.

Fittings and valves should be thoroughly cleaned before applying chlorine to a main. Special attention should be given to mechanical joints, fittings, and valves that may contain spaces that are difficult to chlorinate once they become filled with water.

Table 1 shows the required flow rate to obtain a velocity of 2.5 ft/sec in commonly used sizes of pipe. Flushing can be enhanced by the use of soft pigs to remove dirt, debris, and air from the main prior to disinfection. The use of pigs can also conserve water and is particularly useful when there is insufficient water supply to attain a 2.5 ft/sec minimum flushing velocity.

TABLE 1 – FLOW REQUIRED FOR VARIOUS FLUSHING VELOCITIES				
		Flow Required (gpm) for Given Velocity		
Pipe Size (in.)	Pipe Area (sq. ft.)	1 ft/sec	2.5 ft/sec	5 ft/sec
2	0.02	10	25	50
4	0.09	40	100	200
6	0.20	90	220	440
8	0.35	155	390	780
10	0.55	245	610	1220
12	0.79	350	880	1760
14	1.07	480	1200	2400
16	1.40	625	1570	3140

Preliminary flushing, however, should not be conducted if tablets or granules of calcium hypochlorite have been placed in the pipe during installation. In this case, special care must be exercised in ensuring that the main does not become contaminated with dirt or other materials during construction.

Step 3. Chlorination of Mains

Chlorine is available in three chemical forms:

a) Gaseous Chlorine – Generated from the controlled vaporization of liquid chlorine supplied in 100 or 150-lb steel cylinders through a vacuum-operated chlorinator with a booster pump. The vacuum-operated chlorinator injects chlorine gas into water to form a solution; the booster pump introduces the solution into the main to be disinfected. Direct-feed chlorinators, which operate solely from gas pressure in the chlorine cylinder, are not approved for use due to the danger of chlorine release. Gaseous chlorine application should only be conducted under the direct supervision of a trained operator and in accordance with the safety standards and practices described in the KDHE Policies and Guidelines for Public Water Supply Systems.

b) Sodium Hypochlorite – Available in liquid form in 1 quart to 5 gallon containers and contains approximately 5% to 15%-available chlorine. It includes common household bleaches such as Clorox or Purex that typically contain approximately 5% to 6%-available chlorine. Special precautions must be taken to minimize deterioration of sodium hypochlorite solution in storage.

c) Calcium Hypochlorite (HTH) – Available in granular or tablet form typically containing approximately 65%-available chlorine. The granules dissolve readily in water; the tablets, however, can be more difficult to dissolve. In contrast to sodium hypochlorite, calcium hypochlorite can be stored for extended period of time without significant deterioration. Contact with organic material or high temperatures must be avoided due to the danger of fire or explosion.

AWWA standard C651-92 provides for three methods of chlorination for water mains: tablet, continuous, and "slug". The chlorine dose and minimum contact time for each AWWA method are summarized in Table 2. Recommendations for disinfection of small sections of mains under emergency repair are also included in Table 2. Methods for measurement of free chlorine residual are summarized in Attachment A. Before any disinfection method is utilized, valves must be positioned so that the highly chlorinated water in the main being treated does not flow into water mains in active service.

TABLE 2 – CHLORINATION METHODS FOR DISINFECTING WATER MAINS

Chlorination Method Used	Initial Chlorine Dose (mg/L)	Minimum Contact Time (hours)	Minimum Chlorine Resid. (mg/L)
<u>Nonemergency Procedures</u>			
Tablet	25	24	10
Continuous	25	24	10
Slug	100	3	50
<u>Emergency Procedures</u>			
Premixed Solution or Hypochlorite Injection	300	0.25	100
Swabbing	10,000 (1% sol)	-	Swab thoroughly the interior of pipes and fittings used in repairs

Factors to consider when choosing a method of chlorination include length and diameter of the main, type of joints present, equipment and materials necessary for disinfection, skills and training of personnel, safety concerns, and whether the main must be put into service on a rapid basis. The continuous and "slug" methods require the use of appropriate chlorine feed equipment and the determination of the necessary chlorine feed rate for the chlorine solution. In long, large-diameter mains, the slug method has the potential for reduction in water and chemicals as compared to the continuous method.

The tablet method is convenient to use for mains with diameters less than 24 inches and does not require special chlorine feed equipment. There are, however important limitations with this method: 1) The use of the tablet method precludes preliminary flushing. Flushing of the lines is often necessary to remove dirt and debris and assists in the removal of air from the lines. 2) Calcium hypochlorite granules or tablets may be dislodged from the lines upon filling and accumulate at points of restriction. 3) The tablet method should not be used in large-diameter mains where a worker must enter the main for inspection due to the potential of toxic fumes.

1). Tablet Method – The tablet method consists of preplacing calcium hypochlorite granules or tablets in the main during pipe installation in sufficient amounts so as to obtain a 25 mg/L available chlorine dose. For calcium hypochlorite granules, they should be placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500-ft intervals. For 65%-available chlorine, the quantity of granules necessary for a 25-mg/L-chlorine dose is listed in Table 3 as a function of pipe diameter.

TABLE 3 – AMOUNTS OF CALCIUM HYPOCHLORITE GRANULES TO BE PLACED AT 550-FT INTERVALS FOR 25 mg/L FREE CHLORINE DOSE

Pipe Diameter	Calcium Hypochlorite Granules (65%-available)	
(inches)	(ounces)	(grams)
2	0.4	12
4	1.7	47
6	3.8	107
8	6.7	190
10	10.5	297
12	15.1	427
16	26.8	760

Calcium hypochlorite granules should not be placed in the pipe so as to come in contact with exposed joint compounds such as those used on solvent-welded plastic pipe because of the danger of fire or explosion from the reaction of the joint compound with the calcium hypochlorite.

Instead of granules, calcium hypochlorite 5g tablets can be attached with a food-grade adhesive inside at the top of the main in each section of pipe. The number of 5g tablets required for commonly used sizes of pipes are shown in Table 4.

TABLE 4 – NUMBER OF 5g CALCIUM HYPOCHLORITE TABLETS REQUIRED FOR DOSE OF 25 mg/L*					
	Length of Pipe Section, ft				
Pipe Diameter (inches)	13 or less	18	20	30	40
	Number of 5g Calcium Hypochlorite Tablets				
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1	2	2
8	1	2	2	3	4
10	2	3	3	4	5
12	3	4	4	6	7
16	4	6	7	10	13
*Based on 3.25g available chlorine per tablet; any portion of tablet rounded to next higher integer.					

After installation is complete, the main should be filled with potable water at a velocity no greater than 1 ft/sec (See Table 1 for flow rates corresponding to 1 ft/sec velocity for standard pipe sizes). The chlorinated water must be maintained in the main for at least 24 hours. If the water temperature is less than 41° F (5°C), the water should remain in the pipe for at least 48 hours. At the end of the minimum contact period, the treated water in all portions of the main must have a residual of not less than 10 mg/L free chlorine as confirmed by measurement of the chlorine residual (See Attachment A).

2). Continuous Method

Though this method is referred to as “continuous”, it does not require continuous feeding of chlorine into the main over a 24-hour period. The key feature is that the main is “continuously” in contact with at least 10-mg/L free chlorine concentrations over 24 hours with an initial dose of 25 mg/L.

Procedure 1 – Addition of Premixed Chlorinated Water

In this procedure, hypochlorite is added to potable water in a tanker truck or other large container in sufficient volume to completely fill the main with a chlorine residual of 25 mg/L. The chlorinated water from the tanker truck or large container is then pumped into the main until full as indicated by a discharge through a terminal outlet such as a hydrant. The addition of premixed chlorinated water to the main does not require the feeding of a concentrated chlorine solution or the measurement and control of the filling rate and chlorine solution injection rate.

The minimum amount of calcium hypochlorite (HTH) to achieve a 25-mg/L chlorine dose can be calculated from the known volume of main to be disinfected:

$$\frac{Vol_{main,}\, gal * \frac{1MG}{1\times10^{6}\, gal} * 8.34\frac{lb}{gal} * 25\frac{mg}{L}}{\frac{(\% - available\, Cl)}{100}} = Cl\ as\ lb\, HTH \qquad \text{(Eq. 1)}$$

where,

Vol_{main} = volume of main, gal
*= length(ft) * p[dia(ft)]^2/4 * 7.48 gal/ft^3*

The following equation determines the necessary amount of sodium hypochlorite to achieve a 25 mg/L chlorine dose in a given main:

$$\frac{Vol_{main} * 25\frac{mg}{L}}{Conc_{Cl\,-\,sol},\frac{mg}{L}} = Vol_{Cl\,-\,sol} \qquad \text{(Eq. 2)}$$

where,

Vol_{main} = volume of main, gal
$Conc_{Cl\text{-}sol}$ = concentration of chlorine in sodium hypochlorite solution, mg/L
$Vol_{Cl\text{-}sol}$ = volume of sodium hypochlorite, gal

The quantities of 15%-available sodium hypochlorite or 65%-available calcium hypochlorite (HTH) required to produce a 25 mg/L concentration in water filling a section of main with a length of 100 feet in common diameters are shown in Table 5.

Procedure 2 – Injection of Concentrated Chlorine Solution

An alternate approach is to inject a concentrated chlorine solution into the main while filling. The contractor or operator maintains a desired flow rate of water filling the main through an inlet valve on a temporary connection from the existing distribution system or other approved source. At a point no more than 10 ft downstream from the inlet to the main, the concentrated chlorine solution is pumped into the main at a uniform feed rate until the desired chlorine residual (at least 25 mg/L) is measured in the flushed water at the terminal outlet (see Figure 1). The main is then shut down and the chlorinated water allowed to stand in the pipe for a 24-hour period. At the end of this time period, the treated water in all portions of the main should have a chlorine residual of not less than 10 mg/L free chlorine as confirmed by measurement of the chlorine residual (see Attachment A).

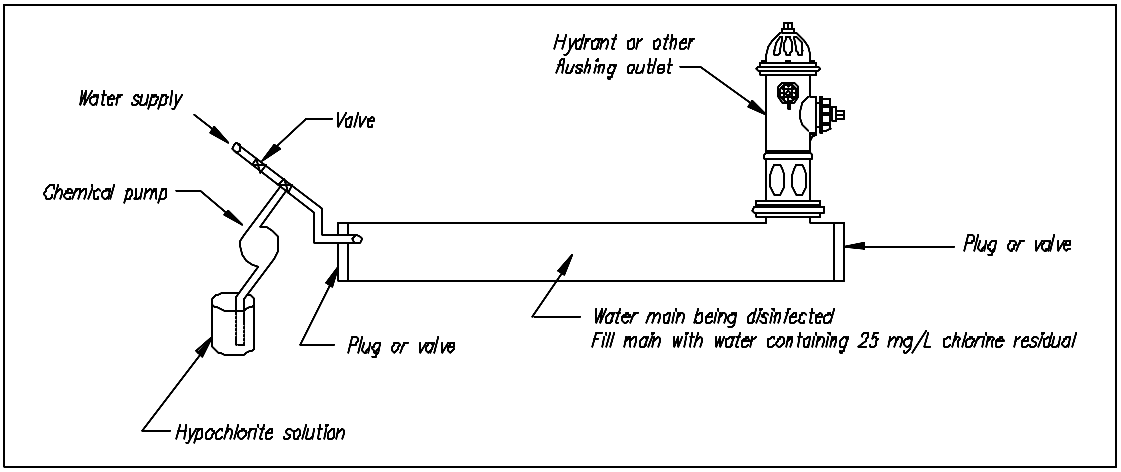

FIGURE 1 – TYPICAL HYPOCHLORITE INJECTION SYSTEM

The concentrated chlorine solution may be prepared from calcium or sodium hypochlorite and injected into the main with a chemical-feed pump designed for chlorine solutions. When calcium hypochlorite is utilized, the HTH should be added to the correct volume of water in order to adequately disperse the heat generated, rather than adding water to the HTH granules or tablets. Feed lines and connections should be of such material and strength as to safely withstand the corrosive effect of the concentrated chlorine solution and the pressure of the pump. The flows of water filling the main and the concentrated chlorine solution must be proportioned so that the resulting chlorine concentration in the main is uniform and at least 25 mg/L (See figure 2).

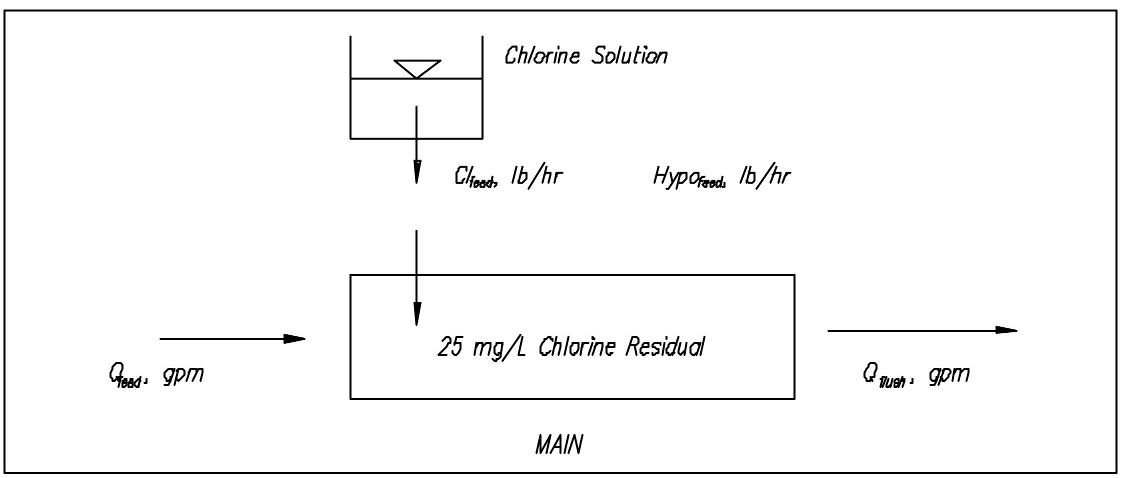

FIGURE 2 – MASS BALANCE DIAGRAM FOR CHLORINE SOLUTION INJECTION

In most cases, the chlorine solution injection rate, $Q_{Cl\text{-}sol}$, will be significantly less than the rate of filling the main, Q_{fill}. When this is true, Q_{fill} may be considered essentially equivalent to the rate of water exiting the main, Q_{flush}. After startup of the chlorine solution injection, the chlorine residual should be checked at the first available outlet, and the hypochlorite injection rate adjusted to obtain at least a 25 mg/L residual.

This approach, the injection of a concentrated chlorine solution into a flowing main, is consistent with the typical chlorination procedure used by operators in disinfecting a continuous flow of water from a well using a hypochlorite feed system. It does, however, require the maintenance of a specific main filling rate (or flushing rate from the outlet of the pipe) as well as a uniform chlorine solution injection rate. Flow rates may be difficult to measure accurately under field conditions that typically involve temporary connections. In addition the use of flow meters, methods for estimating flow rates include measuring the time to fill a container of known volume or measuring the trajectory of the discharge from a hydrant and using the formula in Figure 3.

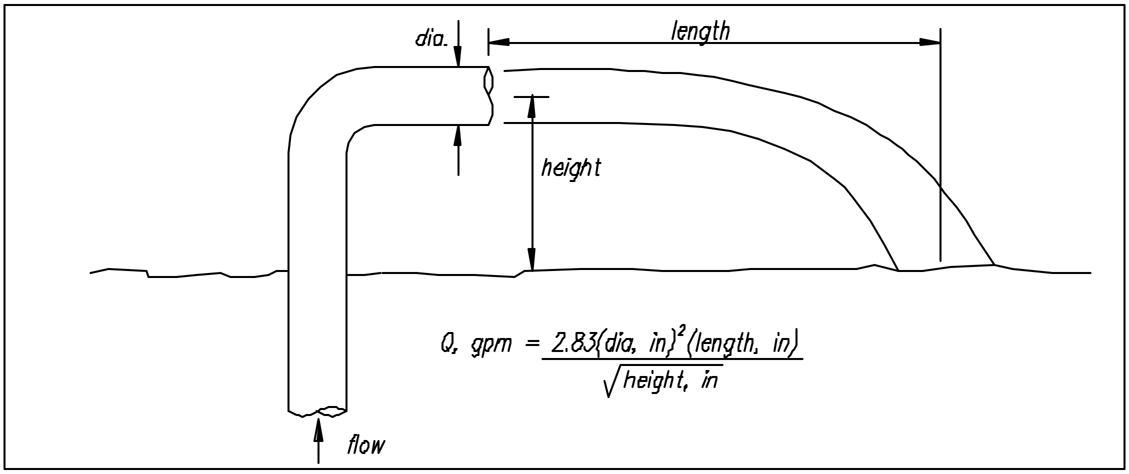

FIGURE 3 – FORMULA FOR ESTIMATING RATE OF DISCHARGE
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The chlorine feed rate into the main, Cl_{feed}, for a 25 mg/L dose (assuming 100%-available chlorine such as supplied by chlorine gas) may be calculated with the following equation:

$$Q_{fill}, \frac{gal}{min} = 1440\frac{min}{day} * \frac{1\,day}{24\,hr} * \frac{1MG}{1\times10^{6}\,gal} * 8.34\frac{lb}{gal} * 25\frac{mg}{L} = Cl_{feed}, \frac{lb}{hr} \qquad \text{(Eq. 3)}$$

where,

Q_{fill} = *flow rate of water filling main (gpm)*
Cl_{feed} – *chlorine feed rate into main (lb of Cl as 100%-avail./hr)*

In chlorine feed rate problems, the chlorine solution injection rate, $Q_{Cl\text{-}sol}$, and the filling rate of the main, Q_{fill}, are typically assumed and fixed. Where the chlorine solution is applied uniformly to the main during filling, the time of filling of the main, T_{fill}, is essentially equivalent to the time of chlorine solution injection, $T_{injection}$:

$$\frac{Vol_{main}, gal}{Q_{fill}, \frac{gal}{min}} = T_{fill}, min = T_{injection}, min \qquad \text{(Eq. 4)}$$

where,

Vol_{main} = *volume of main (gal)*
Q_{fill} = *main filling rate (gpm)*
T_{fill} = *time to fill main (min)*
$T_{injection}$ = *time of chlorine solution injection (min)*

The minimum volume of chlorine solution, prepared from either calcium or sodium hypochlorite, may be determined by multiplying the chlorine solution injection rate by the time of chlorine solution injection:

$$Q_{Cl-sol}, \frac{gal}{min} * T_{injection}, min = Vol_{Cl-sol}, gal \qquad \text{(Eq. 5)}$$

where,

$Q_{Cl\text{-}sol}$ = *rate of chlorine solution injection (gpm)*
$T_{injection}$ = *time of chlorine solution injection (min)*
$Vol_{Cl\text{-}sol}$ = *volume of chlorine solution (gal)*

Use of Calcium Hypochlorite

When calcium hypochlorite is utilized, the chlorine solution feed rate, Cl_{feed} (lb/hr) (see Eq. 3), can be converted to a calcium hypochlorite feed rate, $Ca\text{-}hypo_{feed}$ (lb/hr) by use of the following equation:

$$\frac{Cl_{feed}, \frac{lb}{hr}}{\frac{(\% - available\ Cl)}{100}} = Ca - hypo_{feed}, \frac{lb}{hr} \qquad \text{(Eq. 6)}$$

The total lbs of calcium hypochlorite required for disinfecting a given main are determined by multiplying $Ca\text{-}hypo_{feed}$, (lb/hr) by the injection time, $T_{injection}$, expressed in units of hours or by solving Eq. 1 above:

$$Ca - hypo_{feed}, \frac{lb}{hr} * T_{injection}, hr = Cl\ as\ lb\ HTH \qquad \text{(Eq. 7)}$$

where,

$Ca\text{-}hypo_{feed}$ = *Calcium hypochlorite feed rate (lb/hr)*
$T_{injection}$ = *time of chlorine solution injection (hr)*

The concentration of the chlorine solution, prepared by the addition of the required pounds of HTH to the necessary volume of water, $Vol_{Cl\text{-}sol}$ (Eq. 5), may be calculated by use of the following equation:

$$\frac{Cl\ as\ lb\ HTH}{Vol_{Cl-sol}, gal} * \frac{(\%-avail.Cl)}{100} * \frac{1\times10^{6}\ gal}{1MG} * \frac{1\frac{mg}{L}}{8.34\frac{lb}{MG}} = Conc_{Cl-sol}, \frac{mg}{L} \qquad \textit{(Eq. 8)}$$

where,

$Vol_{Cl\text{-}sol}$ = volume of chlorine solution (gal)
$Conc_{Cl\text{-}sol}$ = chlorine concentration in injected solution (mg/L)

Use of Sodium Hypochlorite

Sodium hypochlorite is available in liquid form as a concentrated chlorine solution expressed typically in percent-available chlorine, where 1%-available chlorine is approximately equivalent to 10,000 mg/L chlorine. Strong solutions of sodium hypochlorite, such as 15%, may be injected directly into a flowing main with a chemical feed pump without the necessity of dilution. In such cases, the concentration of chlorine in the injected solution is known. For an assumed sodium hypochlorite solution injection rate, $Q_{Cl\text{-}sol}$, the filling rate of the main, Q_{fill}, can be determined from the following equation:

$$\frac{Q_{Cl-sol} * Conc_{Cl-sol}, \frac{mg}{L}}{25\frac{mg}{L}} - Q_{Cl-sol} = Q_{fill} \qquad \textit{(Eq. 9)}$$

where,

$Q_{Cl\text{-}sol}$ = rate of sodium hypochlorite solution injection (gpm)
$Conc_{Cl\text{-}sol}$ = chlorine concentration in injected solution (mg/L)
Q_{fill} = main filling rate (gpm)

Table 5 includes the minimum volume of various sodium hypochlorite solutions (1%, 5%, 10%, and 15%) for direct injection into a 100-ft main to prepare a 25 mg/L chlorine dose. Eq. 2 above may also be used to calculate the required volume of chlorine solution as sodium hypochlorite for a given Vol_{main}, Q_{fill}, and $Q_{Cl\text{-}sol}$. For a given Q_{fill}, Eq. 3 above may be utilized to calculate the necessary chlorine feed rate into the main, which is converted to a sodium hypochlorite feed rate by the following equation:

$$\frac{Cl_{feed}, \frac{lb}{hr}}{\frac{(\%-available\ Cl)}{100}} = Sodium-hypo_{feed}, \frac{lb}{hr} \qquad \textit{(Eq. 10)}$$

TABLE 5 – HYPOCHLORITE REQUIRED TO PRODUCE 25 mg/L DOSE IN 100 ft OF PIPE						
		Hypochlorite Solution				Granules
		Percent-Available Chlorine				
Pipe Size (in)	Total Pipe Volume (gal)	1 percent (gal)	5 percent (gal)	10 percent (gal)	15 percent (gal)	65 percent (ounces)
2	16.3	0.34	0.0082	0.0041	0.0027	0.084
4	65.3	1.4	0.033	0.016	0.011	0.34
6	147	3.1	0.073	0.037	0.024	0.75
8	261	5.4	0.13	0.065	0.044	1.3
10	408	8.5	0.20	0.10	0.068	2.1
12	587	12.2	0.29	0.15	0.098	3.0
16	1044	21.8	0.52	0.26	0.17	5.4
Note: 1% chlorine solution = 10,000 ppm or mg/L free chlorine.						

If a sodium hypochlorite solution must be diluted with water to prepare a given volume of less concentrated chlorine solution for injection into the main (e.g., diluting a 15% solution to form a 5% solution), the following equation may be used to determine the necessary volume of concentrated sodium hypochlorite:

$$\frac{(gal\ dil. sol.) * (\%\ dil\ .sol.)}{(\%conc.\ sol.)} = gal\ conc. sol. \qquad (Eq.\ 11)$$

3). Slug Method

The slug method consists of the formation of a solid column or “slug” of chlorinated water in the main with a free chlorine concentration of at least 100 mg/L. This “slug” of highly chlorinated water must flow through the main at a slow enough rate so that all parts of the main and its appurtenances will be exposed to the highly chlorinated water for a period of at least 3 hr. As the “slug” passes tees, crosses, etc. valves must be operated to ensure their disinfection. This method would be appropriate for very large and long mains where continuous feed is impractical. This method could also be used with smaller mains of limited length where due to time constraints; a 24-hour contact time is not available to comply with the continuous method. By application of the higher initial chlorine dose of 100 mg/L, the required minimum contact time is reduced from 24 hours to 3 hours.

The “slug” of chlorinated water would typically be created through the application of gaseous chlorine though hypochlorites could also be used. For relatively small mains, hypochlorite compounds could be added to potable water in a tanker truck or large container such that the chlorinated water has a concentration of at least 100 mg/L free chlorine. The chlorinated water from the tanker truck or large container is then pumped into a section of the main until full as indicated by a discharge through an outlet at the end of the section.

The free chlorine residual must be regularly measured in the “slug” during the required 3- hour minimum contact time. If at any time, the free chlorine residual drops below 50 mg/L, additional chlorine must be applied to the head of the "slug" to restore the free chlorine in the "slug" to not less than 100 mg/L.

Step 4 – Final Flushing of Mains

After the applicable minimum retention period, highly chlorinated water should be flushed from the main until chlorine residual measurements show that the concentration in the water leaving the main is no higher than that generally prevailing in the distribution system. Care must be exercised when disposing of water with high free chlorine residuals. Chlorine is toxic to fish and other aquatic life. Disposal of highly chlorinated water to storm sewers should be avoided without neutralization of the chlorine residual where the sewer discharges directly to a creek, river, or lake.

Neutralization of the chlorine residual remaining in the water can be accomplished by application of a neutralizing chemical such as sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$), sodium sulfite (Na_2SO_3), or sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) in a temporary retention pond, container, or tanker truck. The amount of these chemicals to neutralize various residual chlorine concentrations in 100,000 gallons of water is listed in Table 6. There is also significant reduction of free available chlorine in open ponds or containers primarily due to destruction by sunlight.

TABLE 6 – AMOUNTS OF CHEMICALS REQUIRED TO NEUTRALIZE VARIOUS RESIDUAL CHLORINE CONCENTRATIONS IN 100,000 GALLONS OF WATER

	Chemical Required			
Residual Chlorine Concentration (mg/L)	Sulfur Dioxide (lb)	Sodium Bisulfite (lb)	Sodium Sulfite (lb)	Sodium Thiosulfate (lb)
1	0.8	1.2	1.4	1.2
10	8.3	12.5	14.6	12.0
25	20.9	31.3	36.5	30.0
50	41.7	62.6	73.0	60.0

Adapted from AWWA Standard C651-92.

Step 5 – Bacteriological Tests (Optional)

AWWA Standard C651-92 requires that after final flushing, two consecutive sets of bacteriological samples be collected from the new main. At least one set of samples shall be collected from every 1200 ft of the new main, plus one set from the end of the line and at least one set from each branch. The bacteriological test required is for the presence of coliform organisms in accordance with *Standard Methods for the Examination of Water and Wastewater*. KDHE does not require bacteriological testing of new mains but recommends such tests to confirm the effectiveness of the disinfection procedure. Public water supply systems may require bacteriological testing of mains in their Standard Specifications for Water Main Installations. Unless the provisions of AWWA Standard C651-92 are incorporated by reference in the specifications, specifications for bacteriological testing should provide the following:

1) The type, number, and frequency of samples for bacteriological tests;

2) The method of sample collection;

3) The party responsible for testing; and

4) Laboratory selection requirements.

A brief summary of bacteriological sampling procedures and analytical methods is provided as Attachment B.

Emergency Water Main Disinfection Procedures

When repairs require that mains be opened and depressurized under emergency conditions such as a break or other physical failure of the pipeline, the necessity to restore water service as soon as possible prevents complete compliance with the routine main disinfection procedures of AWWA Standard C651-92. Alternate disinfection procedures under such conditions were described in detail in an article by R. Scott Yoo, “Procedures for Emergency Disinfection of Mains,” *Opflow*, Vol 12, No. 1, (January 1986). The following recommended procedures are based in part on this article:

1) Minimize the entry of contaminants into the repaired main. If possible, repair the break without depressurizing the main by use of clamps, sleeves or other devices. If the main must be shut down and depressurized during repair, excavated areas should be dewatered to the extent practical to prevent dirty water from contacting the pipe. If a pipe is cut and a section removed, examine the inside of the remaining pipe ends and remove pieces of pipe, scale, or other debris. Provide temporary plugs to open ends of pipes.

2) If the main has been depressurized and opened, disinfect the pipe by swabbing with a concentrated chlorine solution or by maintaining a high chlorine residual in the repaired section of main for a brief contact period. The swabbing method is quick and is generally effective under repair conditions that do not pose a threat of significant contamination.

The swabbing method, however, should not be utilized where there is a potential for significant contamination of the main (for example, sewage is detected in the trench during repairs).

a) Swabbing Method. All new pieces of pipe, couplings, clamps, sleeves, and other materials used in repair are thoroughly swabbed with a concentrated (1%-available) chlorine solution to disinfect all surfaces that will come in contact with potable water. The 1% chlorine solution may be prepared by adding 2 ounces of calcium hypochlorite (65%-available chlorine) or 26 fluid ounces of household bleach (5%-available chlorine) to 1 gal of water. The chlorine solution is typically applied using clean rags or a sprayer. Longer pieces of pipe may be disinfected using a clean mop. When working with hypochlorite compounds, proper personal protection should be worn such as rubber gloves, goggles, and respiratory protection under conditions of inadequate ventilation.

b) Hypochlorite Injection or Addition of Premixed Solution. In these methods of disinfection, a high chlorine residual is maintained in the repaired section of main for a brief contact period.

Preliminary Steps – Both methods require the repaired section of main be isolated from the distribution system. This will require the shut off of all service connections along the section of main to be disinfected. Temporary connections for filling the main with water as well as a method of flushing the main through a hydrant or other temporary outlet must be provided. The isolated section of main must be initially flushed to remove dirty water, debris, and air.

Hypochlorite Injection – In the hypochlorite injection method, liquid sodium hypochlorite is injected into the flowing main by means of a chemical-feed pump to achieve a high chlorine residual (see Figure 1). The initial required chlorine dose is 300 mg/L, verified by measuring chlorine residuals in the flushed water through an outlet in the end of the section. The minimum amount of hypochlorite solution, which is required to treat one pipe volume with an initial chlorine dose of 300 mg/L, can be calculated using the following equation:

$$\frac{300\frac{mg}{L}}{Conc_{Cl-sol}} * Vol_{main} = Vol_{Cl-sol} \qquad \textit{(Eq. 12)}$$

where,

$Conc_{Cl\text{-}sol}$ = concentration of chlorine in sodium hypochlorite solution in mg/L, where 1% Cl solution is approximately equal to 10,000 mg/L.
Vol_{main} = volume of main, gal
$Vol_{Cl\text{-}sol}$ = volume of sodium hypochlorite as a chlorine solution, gal

Table 7 includes the minimum volumes of sodium hypochlorite solution (5 and 12.5%-available chlorine) necessary to achieve an initial chlorine dosage of 300 mg/L in 100 feet of main. Volumes in excess of the table values will be necessary because pumping must continue until the minimum chlorine dose is verified at the flushing outlet.

TABLE 7 – HYPOCHLORITE REQUIRED PER 100 FT OF MAIN							
		Hypochlorite Solution				Hypochlorite Granules	
		Gal of 5 percent		Gal of 12.5 percent		Ounces of 65 percent	
Pipe Size (in)	Total Pipe Volume (gal)	Dose 100 mg/L	Dose 300 mg/L	Dose 100 mg/L	Dose 300 mg/L	Dose 100 mg/L	Dose 300 mg?l
2	16.3	0.03	0.10	0.013	0.039	0.33	1.0
4	65.3	0.13	0.39	0.052	0.16	1.3	4.0
6	147	0.29	0.88	0.12	0.35	3.0	9.0
8	261	0.52	1.6	0.21	0.63	5.4	16.1
10	408	0.82	2.4	0.33	0.98	8.4	25.1
12	587	1.2	3.5	0.47	1.4	12.1	36.2
16	1044	2.1	6.3	0.84	2.5	21.4	64.3
Note: 5% chlorine solution = 50,000 ppm or mg/L free chlorine.							

Addition of Premixed Solution – An alternate method is the preparation of a premixed chlorine-water solution in sufficient volume to completely fill the repaired section of main. A hypochlorite compound is added to potable water in a tanker truck or other large container to form a solution with at least 300 mg/L free chlorine (see Table 7). The solution from the tanker truck or large container is pumped into the repaired section of main until the main is full, as indicated by a discharge through a hydrant or other outlet at the other end of the section.

Minimum Contact Period – The minimum contact period for an initial chlorine dose of 300 mg/L is 15 minutes. After the minimum 15-minute contact period, a chlorine residual of at least 100 mg/L should be verified. Lower initial chlorine doses may be used for longer contact periods (e.g., 100 mg/L initial chlorine dose with a 3-hour contact time).

Final Steps – The heavily chlorinated water is flushed from the main until the chlorine residual is reduced to the level normally present in water supplied to the area. Consideration should be given to the collection of bacteriological samples after disinfection is completed to provide a record of the effectiveness of the procedures where repairs were conducted under conditions that posed a threat of significant contamination.

Attachment A

Methods for Total Chlorine Residual Measurement

Methods for determining total chlorine include amperometric titration, colorimetric DPD, titrimetric DPD, and Iodimetric titration. The most widely used method for field test situations is colorimetric DPD. In this method DPD (N,N-diethyl-p-phenylenediamine) is oxidized by chlorine causing a magenta (red) color. The intensity of the color is directly proportional to the chlorine concentration in the sample. Colorimetric DPD field test kits are available from several suppliers. The basic procedure for the DPD Colorimetric method include the following steps:

1) Collect a water sample in the sample tube of the DPD test kit.

2) Add DPD color reagent to the water sample.

3) Match color sample with a color on the comparator to estimate the chlorine residual in mg/L.

Each chlorine test kit is designed to measure total residual chlorine only within a certain range of concentration. The low range instruments typically measure total residual chlorine in concentrations no higher than 3.5 to 5 mg/L. Some manufacturers have produced high range test kits that are capable of measuring chlorine at the level of doses required for disinfection of water mains, e.g. 25 mg/L. However, a low range test kit can be used to measure a chlorine concentration higher than the kit's range by dilution. This dilution method can be performed in two ways:

1) Graduated Cylinder Method

   a) Collect a 2 mL sample of highly chlorinated water and pour the sample into an empty graduated cylinder (50 mL or greater). Add chlorine free water (distilled) for a total of 50 mL and shake gently. Distilled water can be purchased in most grocery and convenience stores in gallon containers.

   b) From the graduated cylinder, collect a sample for total residual chlorine analysis using the DPD test kit in the quantity required for the particular kit. Add DPD reagent and estimate chlorine residual based on a colorimetric comparison with the standard according to the instructions for the particular kit.

   c) Multiply the estimated chlorine concentration by the dilution factor, which is calculated as follows:

$$\frac{(Vol.\ of\ distilled\ \ water + chlorinated\ sample)}{(Vol.\ of\ chlorinated\ sample)} = Dilution\ Factor \quad (Eq.\ A1)$$

   Where 2 mL of sample is combined with 48 mL of distilled water in a graduated cylinder, the dilution factor is 25 as determined below:

$$\frac{(48mL\,of\ \ distilled\ \ water + 2mL\ of\ \ sample)}{(2mL\,of\ \ chlorinated\ sample)} = Dil.\,Factor\,of\ 25 \qquad (Eq.\ A2)$$

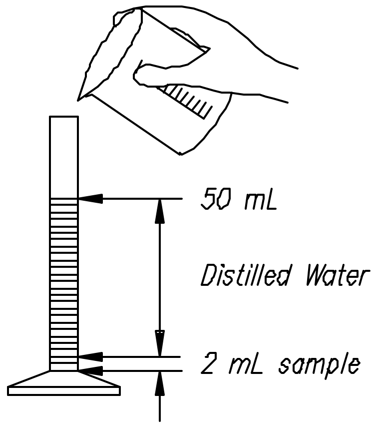

Figure A-1 – Dilution of Sample in Graduated Cylinder

For example, if it is determined that the diluted sample from the graduated cylinder has a chlorine residual of 1 mg/L, the undiluted sample from the disinfected main would have a residual of 25 x 1 mg/L or 25 mg/L. If it is not possible to accurately determine the chlorine residual of the undiluted sample, it may be necessary to provide a different dilution to the sample. For example, if it is anticipated that the chlorine residual is around 100 mg/L (slug method), a more appropriate dilution factor would be 50. This could be obtained by diluting 1 mL of sample with 49 mL of chlorine free water.

2) DPD Drop Dilution Method

a) Add 10 mL of distilled water and one premeasured packet or powder pillow of DPD reagent (or 0.5 mL of DPD solution) to the sample tube of the DPD test kit.

b) Using an eyedropper, add a sample of the highly chlorinated water being tested on a drop-by-drop basis to the sample tube until a color is produced.

c) Record the number of drops added to the sample tube. Assume one drop equals 0.05 mL.

d) Determine the chlorine residual in the sample tube containing the drops of sample, 10 mL of distilled water, and DPD reagent by means of a colorimetric comparison with the stndard according to the specific instructions of the DPD test kit.

e) Estimate the chlorine residual in the chlorinated sample from the disinfected main by use of the following equation:

$$\frac{(Cl\,Residual_{sample-tube}, mg/L) * (Vol_{distilled-water}, mL)}{(Vol_{sample}, drops) * (0.05 mL/drop)} = Cl\,Residual_{sample}, mg/L \quad \text{(Eq. A2)}$$

For example, assume three drops of chlorinated water from the disinfected main produced a chlorine residual of 0.2 mg/L in 10 mL of distilled water in the sample DPD tube. The chlorine residual in the sample of chlorinated water from the disinfected main is determined by use of Eq. A2 as follows:

$$\frac{(0.2 mg/L) * (10 mL)}{(3 drops) * (0.05 mL/drop)} = 13.3 mg/L$$

Attachment B

Bacteriological Sampling and Analysis

AWWA C651-92 provides that two consecutive sets of samples, taken at least 24 hours apart, shall be collected from the main and analyzed for bacteriological contamination. If initial bacteriological samples are unsatisfactory, the new main should be reflushed and additional samples collected and analyzed. According to AWWA C651-92, if any of the check samples are also unsatisfactory, the main must be rechlorinated, reflushed, and resampled until satisfactory results are achieved. KDHE recommends bacteriological testing of newly-installed or repaired mains but does not require it.

Analysis Methods

AWWA Standard C651-92 provides that bacteriological testing of the disinfected main should be conducted in accordance with Standard methods for the Examination of Water and Wastewater and show the absence of coliform organisms. Total coliform is the indicator group of bacteria for use in monitoring drinking water. The Maximum Contaminant Level for total coliforms as determined by the Safe Drinking Water Act is now based on the presence or absence of the indicator bacteria, not on density or direct count. There are four standard laboratory techniques that are approved for coliform analysis:

1) MMO-MUG
2) Multiple tube fermentation (MTF)
3) Presence-absence (PA)
4) Membrane filtration (MF)

The MMO-MUG method is a new technique that is able to confirm the presence of total coliforms in a shorter time frame than the other approved methods. This technique is based on a color change that occurs as the result of the reaction of an enzyme produced by the coliform group of bacteria with the MMO-MUG media. There are several formats currently available for this method. They all involve inoculation in the laboratory of the drinking water sample with a specific quantity of MMO-MUG media. The inoculated sample is incubated at 35°C for 24 hours and observed for development of yellow coloration. If the yellow color is equal to or darker than the minimal standard supplied with the product, the sample contains confirmed total coliforms. The confirmed presence of total coliforms should be interpreted as unsatisfactory requiring reflushing of the main and additional bacteriological samples collected and analyzed.

Several private laboratories located within the state of Knasas are certified for microbiological analysis of drinking water samples. A current list can be obtained from the Public Water Supply Section of KDHE at (913) 296-5514 or the KDHE district offices. The laboratory that is chosen to perform the analysis will typically provide the sampler with appropriate containers for sample collection. The KDHE microbiology laboratory is also available for analysis of bacteriological samples. The KDHE laboratory may be contacted at (913) 296-1637 for request of appropriate sample bottles and scheduling of the analyses. Public Water Supply Systems that currently receive monthly sample bottles for microbial distribution analysis for compliance with the Total Coliform Rule must not utilize their regular monthly bottle allotment for assessing the effectiveness of disinfection procedures on mains. Additional sample bottles must be requested for this sampling effort as a special project.

Number of Samples

AWWA Standard C651-92 provides that at least one set of samples for bacteriological analysis should be collected from every 1,200 ft of the new water main, one set from the end of the line, and at least one set from each branch. If trench water or excessive quantities of dirt has entered the new main during construction, AWWA Standard C651-92 specifies that samples should be taken at intervals of approximately 200 ft and shall be identified by location.

Sample Collection Procedures

1. Use only sterile bottles furnished by the laboratory. Keep the bottles sealed until used. Each sample bottle should contain a dechlorinating agent (typically, sodium thiosulfate) in sufficient amount to neutralize any residual chlorine in the water sample. Do not rinse the bottle prior to taking the sample as such rinsing will remove the dechlorinating agent and render the subsequent sample invalid.

2. Try to avoid collecting your sample from a hose or fire hydrant. Such outlets will often contaminate the sample leading to unsatisfactory results. AWWA Standard C651-92 recommends the use of a specially installed sampling tap consisting of a smooth, unthreaded, ½-inch hose bib. A corporation stop installed in the main equipped with a copper-tube gooseneck assembly can also function as a sampling tap.

3. Be sure that the heavily chlorinated water has been thoroughly flushed from the main before sampling. Run water through the sampling tap at a steady rate 3 to 5 minutes before beginning sampling procedure.

4. Wash hands thoroughly. Remove the bottle lid just before filling, holding the lid in your free hand. Do not contaminate the inner surface of the cap of the bottle with your hands. Fill the bottle to the shoulder or fill line. Do not overflow the bottle or splash water on the outside of the bottle. Replace the lid and tighten securely.

5. Complete the appropriate sample documentation provided by the laboratory. This will typically include a sample label and chain of custody form. If the KDHE laboratory is being utilized, a KDHE Sampling Data Card must be completed instead of a chain of custody form. The KDHE Sampling Data Card requires completion of the following information: collection date, collector's last name and first initial, time of collection, collection location, and chlorine residual.

6. Deliver the samples to the laboratory promptly after collection. There are strict time limits on the amount of time that may elapse between sample collection and analysis before the sample is considered too old to analyze. Check with your laboratory on sample holding time requirements. The KDHE laboratory requires samples reach their lab within 30 hours of collection. Unless special arrangements are made, avoid having the sample arrive at the laboratory on weekends or holidays.

7. Samples should be held at a temperature of 4°C. If practicable, place samples in an iced cooler for storage during transport if transport time will exceed 1 hour. At no time, however, should the sample container be allowed to become immersed or submerged in the ice or melted ice water. Check with your laboratory for specific packaging and transport recommendations.

EXAMPLE CALCULATIONS FOR CHLORINE DISINFECTION OF MAINS

1. FLUSHING RATE – Calculation of the flushing rate for a given velocity (Table 1).

   Example:
   Calculate the flushing rate for a 6-inch diameter pipe that would provide a velocity of 2.5 ft/sec within the main.

   Formulas:
   $Area_{main}$, ft^2 = p[(dia, ft)^2/4]
   Flushing rate, gpm
   = ($Area_{main}$, ft^2) · (Velocity, ft/sec) · (7.48 gal/ft^3) · (60 sec/min)

   Solution:
   $Area_{main}$ = p[(6 in) · (1 ft/12 in)]^2/4 = 0.195 ft^2

   Flushing rate, gpm
   = (0.196 ft^2) · (2.5 ft/sec)·(7.48 gal/ft^3) · (60 sec/min)
   = 220 gpm

2. PREPLACEMENT OF HTH GRANULES IN MAIN – Calculation of the amount of calcium hypochlorite (HTH) granules required for disinfection of a water main with a chlorine dose of 25 mg/L (Table 3).

   Example:
   Calculate the quantity of calcium hypochlorite granules required to disinfect 1,000 feet of a 4-inch diameter PVC pipe. Assume granules provide 65%-available chlorine by weight.

   Formulas:
   Vol_{main}, MG = p(dia, ft)^2/4 · (length, ft) · (7.48 ga./ft^3) · (1 MG/1x10^6 gal)
   Cl needed, lb – (Vol, MG) · (Cl dose, mg/L) · (8.34 lb/gal)

   For calcium hypochlorite,
   Hypochlorite needed, lb = (Cl needed, lb)/(percent-available Cl/100)

   Solution:
   Vol_{main} = p[(4 in) · (1 ft/12 in)^2/4 · (1,000 ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)
   = 0.000653 MG

   Hypochlorite needed for disinfection of 1,000 ft of 4-in pipe
   = (0.000653 MG) · (25 mg/L Cl) · (8.34 lb/gal) · (16 oz/lb) / (0.65)
   = 3.4 oz

   This answer could also be obtained from Table 3, which is expressed in terms of the ounces of calcium hypochlorite granules required at 500 foot intervals. In this example, since the pipe is 1,000 feet long, the amount of granules required must be doubled or 2 x 1.7 oz = 3.4 oz.

3. PREPLACEMENT OF HTH TABLETS IN MAIN – Calculation of the number of 5g calcium hypochlorite tablets (65%-available chlorine) for disinfection of a water main with an initial chlorine dose of 25 mg/L (Table 4).

   Example:
   Calculate the number of 5g calcium hypochlorite tablets (65%-available chlorine) necessary to apply an initial chlorine dose of 25 mg/L to 846 feet of 8-inch diameter PVC pipe.

   Formulas:
   Vol_{main}, MG = p[(dia, ft)^2/4] · (length, ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)
   Hypochlorite needed, lb
   = (Vol, MG) · (Cl dose, mg/L) · (8.34 lb/gal) / (percent-available Cl/100)

   Solution:
   Vol_{main} = p[(8 in) · (1 ft/12 in)]^2/4 · (846 ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)
   = 0.00221 MG

   Hypochlorite needed for disinfection of 846 ft of 8-in pipe
   = (0.00221 MG) · (25 mg/L Cl) · (8.34 lb/gal) / (0.65/100)
   = 0.71 lb

   Number of lb of hypochlorite per 5-g tablet
   = (5 g/tablet) · (0.035274 oz/g) · (1 lb/16 oz) = 0.011 lb/tablet

   Number of tablets providing 0.71 lb of hypochlorite
   = (0.71 lb hypochlorite) · (1 tablet/0.011 lb) = 64.5 tablets

   Since there are approximately 47 sections of 18 feet in an 846-foot length of main, the number of tablets required per 18-foot section is 64.5 tablets/47 sections = 1.37 tablets per section. Assuming partial tablets are not possible, 2 tablets should be used per section of pipe for a total of 94 tablets for the 846 feet of pipe. This solution could also be obtained from Table 4, which indicates that 2 tablets should be used for each 18-foot section of 8-inch pipe.

4. CONTINUOUS METHOD – Procedure 1: Addition of Premixed Chlorinated Water (Table 5)

   Example:
   Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 500 feet of 6-inch main by the addition of premixed chlorinated water. For this problem, calcium hypochlorite is 65%-available chlorine and sodium hypochlorite is a 15%-available chlorine solution.

   Formulas:
   Vol_{main}, MG = p[(dia, ft)^2/4] · (Length, ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)

Utilizing calcium hypochlorite, minimum Cl as lb of HTH =

$(Vol_{main}$, MG) · (8.34 lb/gal) · (25 mg/L) / (percent-available Cl/100)

Utilizing sodium hypochlorite, minimum volume of hypochlorite, gal =

(Vol_{main}) · (25 mg/L) / $(Conc_{Cl\text{-}sol}$, mg/L), where a 1% chlorine solution as sodium hypochlorite is approximately equivalent to 10,000 mg/L chlorine.

Solution:

Vol_{main}, MG = p[(6/12)^2/4] · (500 ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)

= 7.34 x 10^{-4} MG = 734 gal

Utilizing 65% calcium hypochlorite, the required Cl as HTH in lb to be added to 734 gal is the following:

(7.34 x 10^{-4} MG) · (8.34 lb/gal) · (25 mg/L) / (0.65) = 0.24 lb = 3.8 oz

The required gallons of 15% sodium hypochlorite to be added to 734 gal is the following:

(734 gal) · (25 mg/L) / (150,000 mg/L) = 0.12 gal

This solution could also be obtained from Table 5, which indicates that for a 100-ft section of 6-inch diameter main, 0.024 gal of 15% sodium hypochlorite is required, or 0.75 ounces of 65% HTH for a 25 mg/L chlorine dose. Since the problem statement specifies a 500-foot main, the table entries should be multiplied by 5, which provides the minimum quantities of 0.12 gal of 15% sodium hypochlorite or 3.8 oz of 65% HTH.

5. CONTINUOUS METHOD – Procedure 2: Injection of Concentrated Chlorine Solution (Table 5)

Example:

Calculate the amount of hypochlorite (sodium or calcium) necessary for disinfection of 5,250 ft of 8-inch diameter main by the continuous method. For this problem, calcium hypochlorite is 65%-available chlorine and sodium hypochlorite is a 15%-available chlorine solution.

Formulas:

Vol_{main}, MG = p[(dia, ft)^2/4] · (length, ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)

Chlorine feed rate (Cl_{feed}), lb/hr =

$(Q_{fill}$, gpm) · (1440 min/day) · (1 day/24hr) · (1 MG/1x10^6 gal) · (25 mg/L)

Utilizing Calcium Hypochlorite

$Ca\text{-}hypo_{feed}$, lb/hr = $(Cl_{feed}$, lb/hr) / (percent-available Cl/100)

HTH in lb = $(Vol_{main}$, MG) · (8.34 lb/gal) · (25 mg/L) / (percent-available Cl/100)

Chlorine concentration in prepared chlorine solution, mg/L

= (HTH, lb) / $(Vol_{Cl\text{-}sol})$ · (1x10^6 gal/1 MG) · (1 mg/L/8.34 lb/MG) · (percent-available Cl/100)

Utilizing Sodium Hypochlorite

Flow rate of water into main (Q_{fill}), gpm =

$[(Conc_{Cl\text{-}sol}) \cdot (Q_{Cl\text{-}sol}, gpm) / (25 mg/L)] – (Q_{Cl\text{-}sol}, gpm)$

Solution:

$Vol_{main} = p[(8 in) \cdot (1 ft/12 in)^2/4] \cdot (5,250 ft) \cdot (7.48 gal/ft^3) \cdot (1 MG/1x10^6 gal)$

$= 0.0137$ MG

Utilizing Calcium Hypochlorite

Assume a chlorine solution injection rate of 2.5 gal/hr (0.0417 gpm) and a filling rate of 150 gpm.

Cl feed rate in lb/hr =

$(150 gpm) \cdot (1440 min/day) \cdot (1 day/24 hr) \cdot (1 MG/1x10^6 gal) \cdot$
$(8.34 lb/gal) \cdot (25 mg/L)$
$= 1.88$ lb/hr

Calcium hypo feed rate in lb/hr = 1.88 lb/hr/(0.65/100)

= 2.89 lb/hr

Calcium hypochlorite necessary for disinfection of 5,250 ft of main

= (0.0137 MG) · (25 mg/L Cl) · (8.34 lb/gal) / (0.65/100)
= 4.4 lb

The time it takes to fill the main, T_{fill}, which may be assumed equivalent to the period of chlorine solution injection, $T_{injection}$, is determined by dividing the volume of the main by the rate of filling: 13,700 gal/150 gpm = 91 min. For a chlorine solution injection rate, $Q_{Cl\text{-}sol}$, of 0.0417 gpm, the required volume of chlorine solution, $Vol_{Cl\text{-}sol}$, is 3.8 gal. The combination of 4.4 lb of HTH in 3.8 gal of water results in a chlorine solution with a concentration estimated by the following:

Chlorine concentration in solution, mg/L

$= (4.4 lb/3.8 gal) \cdot (0.65/100) \cdot (1x10^6 gal/1 MG) \cdot (1 mg/L/8.34 lb/MG)$
= 90,200 mg/L or approximately a 9% solution.

Utilizing Sodium Hypochlorite

In this case, assume the 15% sodium hypochlorite solution will be pumped into the main without dilution at an injection rate of 2.5 gal/hr (0.0417 gpm). The required main filling rate, Q_{fill}, can be calculated as follows:

Q_{fill}, gpm = [(0.0417 gpm) · (150,000 mg/L)] / (25 mg/L) – 0.0417 = 250 gpm
The required volume of sodium hypochlorite solution is calculated from $T_{injection}$ and the assumed injection rate:

$T_{fill} = T_{injection}$ = 13,700 gal/250 gpm = 55 min

$Vol_{Cl\text{-}sol}$, gal = (55 min) · (0.0417 gpm) = 2.3 gal

An alternative approach is to calculate the required feed rate of sodium hypochlorite. For an assumed main filling rate of 150 gpm (Q_{fill}), a 15% solution, and an injection rate of 2.5 gal/hr (0.0417 gpm), the sodium hypochlorite feed rate ($Hypo_{feed}$) to form a 25 mg/L chlorine dose is calculated from the following equation:

Sodium hypochlorite feed rate (15%-available) in lb/hr) =
= [(150 gpm) · (1440 min/day) · (1 day/24 hr) · (1 MG/1x10^6 gal)
· (8.34 lb/gal) · (25 mg/L) · (0.15/100)
= 12.5 lb/hr

$T_{fill} = T_{injection}$ = 13,700 gal/150 gpm = 91 min

$Vol_{sodium\text{-}hypo}$, gal = (91 min) · (0.0417 gpm) = 3.8 gal of sodium hypochlorite

Sodium hypochlorite in lb
= (12.5 lb/hr) · (91 min) · (1 hr/60 min)
= 18.9 lb

6. SLUG METHOD – Calculation of chlorine necessary for creation of a "slug" of chlorinated water in a main with an initial chlorine dose of 100 mg/L.

Example:
Calculate the amount of chlorine gas required to create a "slug" of chlorinated water of length 5,000 ft in a 16-inch ductile iron main with an initial chlorine dose of 100 mg/L.

Formulas:
Vol, MG
= p[(dia, ft)^2/4] ·(length of "slug", ft) · (7.48 gal/ft^3) · (1 MG/1x10^6gal)

Chlorine (100%-available) needed, lb
= (Vol, MG) · (Cl dose, mg/L) · (8.34 lb/gal)

Solution:
Vol_{main}, MG
= (p[(16 in) · (1 ft/12 in)]^2/4) · (5,000 ft) · (7.48 gal/ft^3) · (1 MG/1x10^6 gal)
= 0.0522 MG

Chlorine (100%-available) needed, lb
= (0.0522 MG) · (100 mg/L) · (8.34 lb/gal)
= 43.5 lb

7. EMERGENCY MAIN DISINFECTION – Calculation of the sodium hypochlorite pumping rate and minimum volume of hypochlorite necessary to establish initial chlorine doses of 100 mg/L and 300 mg/L in a water main (Table 7).

   Example:
   Calculate the sodium hypochlorite pumping rate (5% chlorine solution) and amount of hypochlorite necessary to establish a 300-mg/L chlorine dose in a 300-foot section of 6-inch diameter main. Assume Q_{fill} into the main is 50 gpm.

   Formulas:
   Hypochlorite pumping rate, gpm
   = [(Cl dose, mg/L) / ($Conc_{Cl\text{-}sol}$, mg/L)] · (Q_{fill}, gpm)

   Vol_{main}, gal
   = (p(dia, ft)^2/4) · (Length, ft) · (7.48 gal/ft^3)

   Volume of sodium hypochlorite, gal
   = [(Cl dose, mg/L) / ($Conc_{Cl\text{-}sol}$, mg/L)] · (Vol_{main}, gal)

   Solution:
   Hypochlorite pumping rate, gpm
   = [(300 mg/L Cl residual) / (50,000 mg/L Cl $Conc_{Cl\text{-}sol}$)] · (50 gpm)
   = 0.3 gpm

   Vol_{main}, gal
   = (p[(6 in) · (1 ft/12 in)]^2/4) · (300 ft) · (7.48 gal/ft^3)
   = 441 gal

   Volume of sodium hypochlorite, gal
   = [(300 mg/L) / (50,000 mg/L)] · (441 gal
   = 2.65 gal

   $T_{injection}$ = 2.65 gal/0.3 gpm = 441 gal/50 gpm = 8.8 min

   The amount of sodium hypochlorite required by this problem could also be determined from Table 7. Table 7 indicates for a 6-inch pipe, 0.88 gal of 5% sodium hypochlorite solution is required to establish a 300-mg/L dose in a 100-ft section of main. For a 300-ft section of main, the necessary volume of sodium hypochlorite from Table 7 for a 100-ft section should be multiplied by 3 to give 2.6 gal.